Turbocor Compressor Technology
for liquid chiller applications

Danfoss Turbocor Compressors Inc.
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Introduction
Danfoss Turbocor Compressors

• The world’s first totally oil-free compressors
• Specifically designed for the Heating, Ventilation, Air Conditioning and Refrigeration (HVACR) industry
• The convergence of aerospace and industrially proven technologies which include magnetic bearings, variable-speed centrifugal compression and digital electronic controls

⇒ Enable the Turbocor family of compressors to achieve the highest overall efficiencies for middle-market, water-cooled, evaporative cooled and air-cooled HVAC-R applications
Facts about Danfoss Turbocor
A short history

Turbocor begins as an R&D company in Australia with an international team of designers and engineers
1993

First Turbocor compressors in the field get installed in California
2001

Danfoss Turbocor relocates to Tallahassee Florida to a new state of the art facility with new production standards and the ability to expand the product line
2007

Turbocor moves to Montreal and establishes engineering labs, and training facilities
1999

Danfoss and Turbocor form a 50/50 joint venture called Danfoss Turbocor
2004

Strategic evaluation and decision to become a world class compressor company
2009
Facts about Danfoss Turbocor
Sales split

- **North America**: 50%
- **Europe**: 30%
- **Asia Pacific**: 20%

Sales
20% average growth in core markets
2007 through 2010

**Plant**: 72,500 square feet

**Location**: Tallahassee, Florida

**Employees**: ~215

**Markets**: Core - USA, Europe, Australia
New - China and India

**Product**
- ~20,000 compressors running in the field
- ~40 million operating hours
- Current installed base is saving about 750,000 tons of CO2 and 950,000 mWH of electricity annually
Facts about Danfoss Turbocor

Recognition

Danfoss Turbocor is certified
ISO 9001:2000

Making a world of difference.
What are the current drivers for building owners & consultants today?

- Capital costs
- Reliability
- Floor space
- Comfort / Noise
- Life cycle costs
- Return on investment

However, a wave is now heading for high efficiency and green!
The advantages of the Turbocor technology

Many people see its advantages in different ways, some of these include:

- HFC refrigerant for optimum environmental position
- Outstanding part load efficiency
- High full load efficiency
- Intelligent, self-contained control
- Light weight
- Low vibration
- **Oil free operation** reduces complexity and cost, improves heat exchange efficiency and eliminates disposal issues
- Very low sound
- Soft starting
- Small footprint
The advantages of the Turbocor technology

The energy efficiency

Turbocor is one of the most efficient compressors in the world

This achievement comes from several factors, among these are:

- The bearing technology
- The motor technology
- The power electronics technology
- The compression technology and

- The combination of all of these features into one product
The advantages of the Turbocor technology

Oil free technology

**Typical screw water-cooled chiller**

- Eliminate oil film on heat transfer surfaces
- Eliminate stacking of oil in evaporator at lower loads
- No disposal required
- No oil heater and cooler
- No oil separator
- No oil pump, oil solenoid valves, oil filter

**Oil-free water-cooled chiller**

- Eliminate oil film on heat transfer surfaces
- Eliminate stacking of oil in evaporator at lower loads
- No disposal required
- No oil heater and cooler
- No oil separator
- No oil pump, oil solenoid valves, oil filter
- No oil pressure transducer

→ Simplify application and reduce cost

Making a world of difference.
Performance comparison

The first cost component (design, equipment procurement and construction) is small compared to the total cost of ownership.
Description of the Turbocor technology
It’s a fully integrated system

- Inverter speed control
- 2-stage centrifugal compressor
- Pressure and temperature sensors
- Inlet guide vanes
- Motor and bearing control
- Permanent magnet motor
- Soft-Starter

Making a world of difference.
Description of the Turbocor technology
The working end

It is a centrifugal compressor that:

• Is two stage
• Has an economizer feature
• Operates on R134a
• Has infinitely variable capacity control
• Uses guide vanes and diffusers to optimize its performance
• Does not require oil for compression sealing
Description of the Turbocor technology
Magnetic bearings

Magnetic bearings contribute to the most efficient, reliable, quiet, and low maintenance centrifugal compressors available:

- Radially and axially located magnetic bearings prevent contact between rotor and other metallic surfaces

- Touchdown bearings support the rotor when the compressor is not energized
Description of the Turbocor technology
Magnetic bearing system

Making a world of difference.
Description of the Turbocor technology
Magnetic bearing system

- 5 axis proximity sensors
- Digital controller
- 5 separate pulse width modulators (PWM)
- Movements of less than 0.00002" are sensed and adjustments are made accordingly 100,000 times per second
Description of the Turbocor technology

The motor

The motor is a permanent magnet design that enables the compressor to have:

- Low starting current (2 amps compared to 500 amps)
- High reliability - minimal stress on the stator windings
- High efficiency throughout its operating range
- Lower cost – Size greatly reduced because of high operating speed
- High efficiency and compactness

120kW motor the same size as a .75kW motor
Description of the Turbocor technology
Safeties with no added costs

• Inbuilt diagnostics
• Modbus communication
• 216 Modbus registries
• Diagnostics on:
  – Motor
  – Bearings
  – Compressor
  – Expansion valves
  – Events
  – Faults
  – Trends
  – Chiller
  – And more …

<table>
<thead>
<tr>
<th>COMPRESSOR PROTECTION</th>
<th>Extra cost</th>
<th>Turbocor</th>
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</thead>
<tbody>
<tr>
<td>Bearing Oil High Temperature</td>
<td></td>
<td>Not Required</td>
</tr>
<tr>
<td>Motor High Temperature</td>
<td></td>
<td>Built In</td>
</tr>
<tr>
<td>Refrigerant (Condenser) High Pressure</td>
<td></td>
<td>Built In</td>
</tr>
<tr>
<td>Refrigerant (Cooler) Low pressure</td>
<td></td>
<td>Built In</td>
</tr>
<tr>
<td>Lube Oil Low Pressure</td>
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<td>Not Required</td>
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<tr>
<td>Compressor (Refrigerant) Discharge Temperature</td>
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<td>Built In</td>
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<td>Under Voltage</td>
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<td>Built In</td>
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<tr>
<td>Over Voltage</td>
<td></td>
<td>Built In</td>
</tr>
<tr>
<td>Oil Pump Motor Overload</td>
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<td>Not Required</td>
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<tr>
<td>Cooler and Condenser Water Flow</td>
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<tr>
<td>Motor Overload</td>
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<td>Built In</td>
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<tr>
<td>Motor Acceleration Time</td>
<td></td>
<td>Built In</td>
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<tr>
<td>Intermittent Power Loss Protection</td>
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<td>Built In</td>
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<tr>
<td>Compressor Starter Fault</td>
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<td>Built In</td>
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<tr>
<td>Compressor Surge Protection</td>
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<td>Built In</td>
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<tr>
<td>Low Level Ground Fault</td>
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<td>Built In</td>
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<tr>
<td>Low Level - Phase to Phase and Phase to Ground Protection</td>
<td></td>
<td>Built In</td>
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Description of the Turbocor technology

The controls

[Image of Turbocor technology interface with various data points such as Ts[sat], 38.6°F, Tc[sat], 96.8°F, 70.3 kW, 23185 RPM, 62.5% Compressor Demand, 117 psig Discharge Pressure, 40.7 °F Suction Temperature, 110% IGV% Open, 34 psig Suction Pressure, 69.0 °F Discharge Temperature, and no faults, no alarms, interlock status - closed.]
The electronics have been designed specifically to maximize the potential of all the technologies within the compressor, this means:

- Maximum energy efficiency
- Low vibration miniaturized design
- Optimized product costs
- Higher reliability
- More efficient component cooling
Description of the Turbocor technology
The first intelligent compressor

The Turbocor compressor was the world’s first digital compressor, with:

- Digitally controlled bearings
- Digitally controlled power electronics
- Digitally controlled compressor control
- Digitally controlled chiller control
- Digitally controlled expansion valve control
Description of the Turbocor technology
Small footprint

→ Size & weight does matter, valuable plant room space can be reduced

Under 300 lbs is a fraction of the weight of conventional compressors with an approximate 50% smaller footprint
Description of the Turbocor technology
Small footprint

350 Ton

270 - 600 Ton
Description of the Turbocor technology

Noise sensitive applications

<table>
<thead>
<tr>
<th>Operational Mode of Compressor (Capacity)</th>
<th>TT300</th>
<th>TT400</th>
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<tbody>
<tr>
<td><strong>Distance</strong></td>
<td><strong>250 kW</strong></td>
<td><strong>315 kW</strong></td>
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<tr>
<td>Meters Feet</td>
<td>(70 Ton)</td>
<td>(90 Ton)</td>
</tr>
<tr>
<td>1 3</td>
<td>72.5 dBA</td>
<td>78 dBA</td>
</tr>
<tr>
<td>5 16</td>
<td>59.5 dBA</td>
<td>64 dBA</td>
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Description of the Turbocor technology
Refrigerant

- Current used refrigerant R134a

Future refrigerants
- Danfoss Turbocor is currently investigating in other refrigerants
The TT series of compressors
Product portfolio

Air-Cooled & Water-Cooled

Water-Cooled Only

TT300
TT350
TT400
TT500

60-90Ton* (200-315kW*)
90-120Ton* (315-420kW*)
100-150Ton* (350-525kW*)
140-200Ton* (500-700kW*)

*Nominal capacities are based on water-cooled application. Capacity may vary depending on actual running conditions.

Making a world of difference.
Applications

Making a world of difference.
Danfoss Turbocor Compressors
Making a World of Difference